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(54) Method and apparatus for treating or utilizing a hot gas flow.

(57) A method and apparatus for cooling hot gas in a reactor (10) in which the lower section of the reactor is provided with an inlet (16) for hot gas and a chamber (12) encompassing a bubbling fluidized bed (14), the middle section is provided with a riser (22), and the upper section with a gas outlet (30), and the reactor has heat transfer surfaces (24, 44, 46) for recovering heat from solid particles. The riser is defined by vertical walls (24), which are arranged above the bubbling fluidized bed so that they divide the fluidized bed into an outer (12') and inner (12") part. From the inner part (12") of the fluidized bed (14) solid particles are supplied to the hot inlet gas for cooling thereof. The gas containing solid particles is conveyed through the riser (22) into the upper section of the reactor, where solid particles are separated from the gas in a particle separator (28) and returned to the fluidized bed into the outer part (12') thereof.

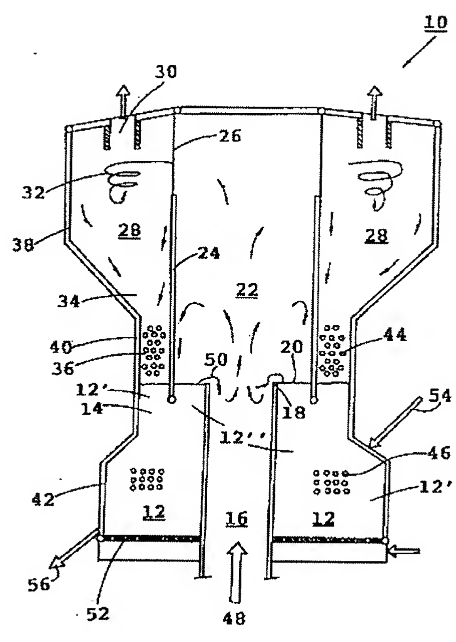

FIG. 1

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The present invention relates to a method and apparatus for cooling or utilizing hot gas in a reactor in which the lower section of the reactor is provided with a hot gas inlet and a chamber encompassing a fluidized bed, the middle section is provided with a riser, and the upper section with a gas outlet, and the reactor has heat transfer surfaces for recovering heat form solid particles. The invention especially relates to a method, in which hot gas is introduced through the inlet into the lower section of the reactor, and solid particles from the bubbling fluidized bed are fed to the inlet gas for cooling thereof, solid particles are separated from the cooled gas and returned to the fluidized bed, heat is recovered from the separated solid particles, and the cooled gas is discharged through the gas outlet.

Fluid bed reactors are well applicable to cooling of hot gases containing molten and/or vaporized components and/or tar-like particles. Gas coolers are suited to, e.g., cooling of exhaust gases from industrial plants and dry purification of gases containing dust and tar and other condensing components, which gases have resulted from partial oxidation of biomass, peat or coal. The hot gases introduced into the reactor are efficiently cooled by mixing solid particles therewith, such solid particles having been cooled in the reactor earlier.

Finnish patent 64997 teaches cooling of hot gases in circulating fluidized bed reactors. Here hot gases are fed as fluidizing gas into the mixing chamber of the reactor, where the gases cool efficiently as they come into contact with a large amount of solid particles, i.e., bed material. Solid particles are carried by the gas flow through the riser into the upper section of the reactor, where they are separated and then returned to the fluidized bed in the mixing chamber. In the riser, the gas flow conveying solid particles is cooled by heat transfer surfaces.

A drawback of the method described above is, however, that the hot gases to be cooled have to fluidize a large amount of solid particles, whereby the power requirement is high. On the other hand, a sudden interruption in the power supply may result in the entire bed flowing through the inlet and further out of the reactor.

Finnish patent application 913416 also teaches cooling of hot process gas in a stationary fluidization, i.e., a so-called bubbling fluidized bed. Here the hot gas flowing into the reactor is supplied with solid particles as an overflow from the bubbling fluidized bed. The gas and the solid particles entrained therewith flow into a dust collector disposed above the bubbling fluidized bed, wherefrom solid particles then drop back onto the surface of the bubbling fluidized bed as the flow rate of the gas quickly decreases. The bubbling fluidized bed and the gas riser, which is disposed above the dust collector, are provided with heat transfer surfaces.

In the arrangement described above, the particles fallen onto the surface of the bubbling fluidized bed are fast carried along the surface back to the overflow point, where they are immediately taken to recirculation ending up in the dust collector. Thus, a separate "surface circulation" of hot particles is developed above the fluidized bed. These particles do not cool efficiently in the fluidized bed because the particles which are deeper down in the fluidized bed, near the heat transfer surfaces, cannot mix efficiently with the particles present in the "surface circulation".

In the method described above, the riser is considered a natural place for the heat transfer surfaces because the solids and gas flows are swift therein. The gas stream, however, causes wear of the heat transfer surfaces in the riser. Wear is partly attributable to the composition of the gas as well as to the dust contained therein and partly to the high flow rate of the gas.

In some cases, the hot gas flowing to the reactor may cause fouling and clogging of the heat transfer surfaces when the gas may enter the heat transfer surfaces too hot. If the hot gas does not cool until it touches the heat transfer surfaces, the impurities will correspondingly condense on or adhere to these surfaces, and not on the circulating mass particles as is normally intended.

Especially the chlorine-containing gases cause corrosion in hot conditions and, therefore, superheating of steam to high temperatures is not usually possible in the heat transfer surfaces of the riser, whereas SO_3 may cause problems with the heat transfer surfaces at low temperatures.

It is an object of the present invention to provide an improved method and apparatus, when compared with the above-described ones, for cooling or utilizing hot gases in the hot gas treatment of solid material.

It is especially an object to provide a method and apparatus for minimizing power consumption and wear of the heat transfer surfaces.

It is another object of the present invention to provide a method and apparatus by means of which the heat energy released by the hot gas when it cools may be utilized as efficiently as possible, e.g., for generation of superheated steam.

For achieving the above objects, it is characteristic of the method of the invention for cooling hot gas in a reactor with a bubbling fluidized bed that the cooled gas containing solid particles is conveyed through the riser, which is defined by substantially vertical walls, and introduced into the upper section of the reactor, where solid particles are separated from the gas in a particle separator, that the separated solid particles are returned to

the bubbling fluidized bed into the outer part thereof, that heat is recovered from separated solid particles in a return duct, fluidized bed and/or riser and that solid particles from the inner part of the bubbling fluidized bed are fed into the hot inlet gas.

Correspondingly, it is characteristic of the apparatus of the invention for cooling hot gas in a reactor with a bubbling fluidized bed that the reactor comprises

- a riser defined by substantially vertical walls and being arranged above the bubbling fluidized bed,
- at least one particle separator arranged in the upper section of the reactor,
- at least one return duct to connect the particle separator with the outer part of the fluidized bed, for returning the solid particles separated in the particle separator to the outer part of the fluidized bed,
- heat transfer surfaces disposed in the return duct and/or in the fluidized bed, and
- means for leading solid particles from the inner part of the fluidized bed towards the hot gas inlet.

According to a preferred embodiment of the invention, solid particles may be conveyed as an overflow from the bubbling fluidized bed and directed toward the hot gas flowing through the inlet. On the other hand, the wall between the hot gas inlet and the chamber encompassing the fluidized bed may be provided with openings wherethrough solid particles are introduced into the hot gas flow. Due to a higher static pressure of the fluidized bed, solid material automatically flows through the openings to the hot gas flow, but it may also be conveyed by a transporting gas through the openings into the gas flow.

In the reactor according to the invention, hot gas is cooled to a substantially lower temperature immediately at the gas inlet by mixing cooled solid particles with the gas, whereby the gas cools and the solid particles are correspondingly heated. Besides cooling of gases, the invention may be employed in processes where solid material is heated with hot gases, such as, e.g., heating of lime with hot gases.

In a reactor according to the invention, gas may also be cooled in the riser, whereby the riser is defined by cooled surfaces, such as for example superheating panels. In the upper section of the reactor, solid particles are separated in a particle separator from the gas which is then exhausted from the reactor. The solid particles are conveyed as a dense suspension, almost as a plug flow, via the return duct back to the bubbling fluidized bed. In the return duct is preferably disposed heat recovery surfaces for recovering the heat energy released by heated solid particles, the heat recovery surfaces being preferably arranged in the dense suspension area.

The return duct is a favourable location for heat transfer surfaces because the particle density is relatively high there, which is beneficial in respect of heat transfer, and because the return duct contains much fewer corrosive gaseous components than, e.g., the riser. Neither does hot gas containing molten or condensing components, which might clog the heat transfer surfaces, flow into the return duct.

Heat transfer surfaces may also be disposed in the fluidized bed itself, where flowing is slow and thereby favourable for the durability of the heat transfer surfaces.

A portion of the solid particles which are first carried upwardly entrained with the gas, flows down along the riser walls, back to the lower section of the reactor. This portion is partly cooled provided that the wall is a cooling surface. Cooling of the solid particles may be further improved by providing the lower section of the wall with a pocket which collects the solid particles flowing down along the wall and then leads them to the lower section of the return duct, preferably to a place equipped with heat transfer surfaces. Thus, also a portion of those solid particles which the gas is not capable of carrying as far as to the particle separators, is subjected to efficient heat transfer.

The method and apparatus according to the invention provides a simple arrangement for minimizing wear of heat transfer surfaces in the gas cooler. At the same time, power consumption is lowered in comparison with other arrangements used. Furthermore, in the arrangement according to the invention, the heat energy released by the gases is well utilized, e.g., by generating superheated steam.

The invention will be described in more detail, by way of example, with reference to the accompanying drawings, in which

Fig. 1 is a schematic illustration of a reactor arrangement according to the invention;

Fig. 2 is a schematic illustration of a second reactor arrangement according to the invention; and

Fig. 3 is a schematic illustration of a third reactor arrangement according to the invention.

Fig. 4 is a schematic illustration of a fourth reactor arrangement according to the invention.

Fig. 1 illustrates a reactor 10 for cooling or utilizing hot process gases. The reactor 10 comprises an annular chamber 12 which has an open top and which is disposed in the lower section of the reactor. The chamber has an outer part 12' and

an inner part 12" and is provided with a bubbling fluidized bed 14. In the centre of the annular chamber is disposed an inlet duct or conduit 16 for hot gases, the top edge 18 of which equals the bubbling fluidized bed top surface 20.

On top of the chamber 12 is arranged a cylindrical riser 22 of the reactor, the diameter of the riser being larger than that of the inlet duct 16 but smaller than that of the annular chamber 12. The cylindrical riser 22 is defined by cooling panels 24. The upper part of the riser is provided with openings 26, which bring the riser into contact with particle separators 28, which are structurally integrated with the riser. The inlet duct or conduit 16, chamber 12, and riser 22 may naturally be square, rectangular or in some other shape. In the embodiment of Fig. 1, the walls of the riser extend down to the fluidized bed. In some arrangements, the walls may end a little bit above the fluidized bed.

The particle separators 28 form an annular space around the cylindrical riser 22. The riser walls 24 constitute the inner walls of the particle separators. The particle separators are cyclone separators, where gas outlets 30 and inlet 26 provide a vortex flow per each outlet. The lower section 34 of the particle separator is in communication with a return duct 36, which connects the particle separator with the fluidized bed 14. The return duct forms an annular slot around the riser. The wall 24 of the riser 22 constitutes the inner wall of the return duct. The outer wall 38 of the particle separator, outer wall 40 of the return duct and outer wall 42 of the annular chamber 12 may all be of one and the same construction, e.g., membrane panel, which has been bent to a desired shape.

The return duct 36 is provided with heat transfer surfaces 44. The fluidized bed 14 is also provided with heat transfer surfaces 46.

The reactor functions so that hot gas 48 is introduced into the reactor through an inlet duct 16, which hot gas is mixed with cooled solid particles by flowing these as an overflow 50 over the inlet duct edges 18. The hot gas cools very quickly by releasing heat energy to solid particles.

The gas and solid particles entrained therewith flow as a suspension upwardly in the riser 22. A portion of the particles is separated from the gas and flows along walls 24 back to the fluidized bed, simultaneously releasing heat energy to the walls. The gas suspension flows via inlet opening 26 to the particle separator 28, where solid particles are separated from the gas. Purified and cooled gases are led out of the reactor through the outlet 30.

The separated solid particles are allowed to flow by gravity downwardly in the return duct 36. Solid particles cool while releasing part of their heat energy in the heat exchanger 44. Solid particles further cool in the fluidized bed by the effect of the heat exchanger 46.

Appropriate fluidizing, in respect of both overflow and heat transfer, is maintained in the fluidized bed by leading fluidizing air or fluidizing gas through nozzles 52 into the annular chamber. The amount of solid particles in the reactor may be regulated by adding particles via conduit 54 or by discharging them via conduit 56.

Fig. 2 illustrates a second way of applying the arrangement of the invention. Corresponding items of Figs. 2 and 1 are denoted with the same reference numerals. Fig. 2 especially shows another arrangement for leading solid particles from the fluidized bed 14 into the hot gas inlet duct and a new arrangement for leading the particles flowing along the riser walls 24 into the fluidized bed 14.

The hot gas inlet duct 16 is provided with openings 60 wherethrough solid particles from the fluidized bed flow into the inlet duct. The pressure difference between the fluidized bed 14 and the inlet duct 16 functions as a carrying force. The particles flowing into the inlet duct are immediately mixed with the hot gas and are carried therewith up into the riser 22.

The wall 24 of the riser 22 is provided with an internal pocket 62 which is connected with the return duct 36 via an opening 64. In the riser, a portion of the particles flowing upwardly with the gases loses their speed and starts to flow downwardly along walls 24. These particles end up in the pockets 62, wherefrom they may be led via openings 64 into the return duct. In the return duct, the particles cool efficiently while passing by the heat transfer surfaces 44. By this arrangement it is possible to intensify the cooling of particles if the capability of the heat transfer surfaces of the walls 24 is insufficient for cooling the particles.

In the arrangement shown in Fig. 2, the cross section of the inlet duct 16 for hot gases has the shape of an elongated slot. Correspondingly, the cross section of the riser has the shape of an elongated rectangle, and the fluidized bed 14 is arranged in two rectangular chambers which are of the same length as the substantially slot-shaped inlet duct 16 and which are disposed on both sides thereof. The particle separators 28 are also rectangular in cross section, and they are parallel with the riser and arranged on both sides thereof.

Fig. 3 illustrates a third exemplary way of applying the arrangement of the invention for treating hot gases. Items corresponding to those of Fig. 1 are denoted with the same reference numerals. Differently from the arrangement shown in Fig. 1, the riser 22 in Fig. 3 is of a fire tube construction. The riser is provided with two horizontal tube plates 70 and 72, which are similar to the cross section of the riser in shape. Between the tube plates are

disposed ducts 74 to connect the riser space 76 below the tube plates with the riser space 78 above the tube plates. The free space 80 between the ducts 74 is filled with heat transfer medium, such as water or air.

In the arrangement of Fig. 3, the gas suspension produced in the lower section of the riser is conveyed through ducts 74 to the upper section 78 of the riser. The gas suspension flowing in the ducts is cooled indirectly with heat transfer medium. By employing the fire tube arrangement, cooling of solid material may be intensified already in the riser, especially in low pressure arrangements.

Fig. 4 illustrates a reactor 10 for cooling or for utilizing hot process gases. The reactor 10 comprises a chamber 12 which has an open top and which is disposed in the lower section of the reactor. The chamber has an outer part 12' and an inner part 12" and is provided with a bubbling fluidized bed 14. In the centre of the chamber is disposed a duct or conduit 16 for hot gases, the top edge 18 of which equals the level of nozzles 52 for introducing fluidizing gas to the bubbling fluidized bed 14.

On top of the chamber 12 is arranged a riser 22 of the reactor. The upper part of the riser is provided with openings 26, which bring the riser into contact with particle separators 28, which are structurally integrated with the riser. The inlet duct or conduit 16, chamber 12, and riser 22 may naturally be square, rectangular or in some other shape.

The particle separators are cyclone separators, where gas outlets 30 and inlet 26 provide a vortex flow 32 per each outlet. The lower section 34 of the particle separator is in communication with a return duct 36, which connects the particle separator with the fluidized bed 14. The fluidized bed 14 is provided with heat transfer surfaces 46.

The reactor functions so that hot gas 48 is introduced into the reactor through an inlet duct 16, which hot gas is mixed with cooled solid particles by flowing these as an overflow 50 over the inlet duct edges 18. The hot gas cools very quickly by releasing heat energy to solid particles. In this embodiment, the upper surface of the bed 14 extends higher than the edge 18 of the duct 16. By appropriate adjusting of the fluidization, e.g., by arranging separated, separately controllable zones 52', 52", it is possible to arrange the bed upper surface to be at a higher level than the top edge of the duct 16. This also means that the top level of the bed 14 is maintained above the level of the edge 18. In this arrangement, the length of the inlet duct is minimized. So, in this arrangement the gas flow is introduced through the inlet duct 16 into the lower section of the reactor at the level substantially equal to the level of nozzles 52 for introducing fluidization gas into the fluidized bed 14. This feature is of benefit specially in cases when the gas flow 48 contains large amounts of fouling components. Mixing of cooled particles and gases takes place mainly at section above the edge 18 so that the suspension is in contact with solid particles of bed 14, and essentially not with a solid wall, which diminishes the clogging tendency of the inlet duct 16. The top portion to the duct 16 may even be constructed to be in form of a downwardly opening cone resulting in a very thin top of edge 18, which even more diminishes the contact area with the solid wall structure.

The gas and solid particles entrained therewith flow as a suspension upwardly in the riser 22. The gas suspension flows via inlet opening 26 to the particle separator 28, where solid particles are separated from the gas. Purified and cooled gases are led out of the reactor through the outlet 30.

The separated solid particles are allowed to flow by gravity downwardly in the return duct 36. Solid particles cool in the fluidized bed by the effect of the heat exchanger 46.

Appropriate fluidizing, in respect of both the flow of particles into the duct 16 and the heat transfer, is maintained in the fluidized bed by leading fluidizing air or fluidizing gas through nozzles 52 into the chamber.

It is not an intention to limit the invention to the examples described above, but, on the contrary, to apply it to different modifications within the scope of invention defined by the accompanying claims.

Claims

1. A method of cooling hot gas in a reactor (10) in which the lower section of the reactor is provided with a hot gas inlet duct (16) and a chamber (12) encompassing a fluidized bed (14), the middle section is provided with a riser (22), and the upper section with a gas outlet (30), and the reactor has heat transfer surfaces (22, 44, 46) for recovering heat from solid particles, whereby
    - hot gas is introduced through the inlet duct (16) into the lower section of the reactor,
    - solid particles from the bubbling fluidized bed (14) are fed into the hot inlet gas for cooling thereof,
    - solid particles are separated from the cooled, solids-containing gas and returned to the fluidized bed,
    - heat is recovered from the separated solid particles, and the cooled gas is discharged from the reactor via the gas outlet (30),

characterized in that
- the cooled gas containing solid particles is conveyed through the riser (22), which is defined by substantially vertical walls (24), and introduced into the upper section of the reactor, where solid particles are separated from the gas in a particle separator (28),
- the separated solid particles are returned to the bubbling fluidized bed into the outer part (12') thereof,
- heat is recovered from separated solid particles in a return duct (36), fluidized bed (14) and/or riser (22) and that
- solid particles from the inner part (12") of the bubbling fluidized bed are fed into the hot inlet gas.

2. A method as recited in claim 1, **characterized in that** solid particles from the inner part (12") of the fluidized bed are fed as an overflow over the edge (18) into hot gases.

3. A method as recited in claim 1, **characterized in that** solid particles from the inner part (12") of the fluidized bed are introduced into the hot gases through openings (60) of the inlet duct by employing a transporting gas.

4. A method as recited in claim 1, **characterized in that** solid particles are cooled on heat transfer surfaces (44) disposed in the return duct (36).

5. A method as recited in claim 1, **characterized in that** solid particles are cooled on heat transfer surfaces (46) in the fluidized bed (14).

6. A method as recited in claim 5, **characterized in that** solid particles are cooled on heat transfer surfaces (46) in the outer part (12') of the bubbling fluidized bed.

7. A method as recited in claim 1, **characterized in that** the gas flow is conducted from the riser (22) into two, preferably a plurality of particle separators (28), wherefrom the separated solid particles are returned via two, preferably a plurality of return ducts (36) to the bubbling fluidized bed (14).

8. A method as recited in claim 1, **characterized in that** the gas flow is introduced through the inlet duct (16) into the lower section of the reactor at the level equal to or above the level of nozzles (52) for introducing fluidization gas into the fluidized bed (14).

9. A method as recited in claim 8, **characterized in that** the gas flow is introduced through the inlet duct (16) into the lower section of the reactor at the level equal to the level of nozzles (52) for introducing fluidization gas into the fluidized bed (14).

10. An apparatus for cooling hot gases in a reactor (10) in which the lower section of the reactor is provided with a hot gas inlet duct (16) and a chamber (12) encompassing a fluidized bed, the middle section is provided with a riser (22), and the upper section with a gas outlet (30), and the reactor has heat transfer surfaces (24, 44, 46) for recovering heat from solid particles, **characterized in that** the reactor comprises
- a riser (22) defined by substantially vertical walls (24) and being arranged above the bubbling fluidized bed (14) so that the lower portion of the riser walls (24) partly divides the fluidized bed into an outer (12') and inner (12") part,
- at least one particle separator (12) arranged in the upper section of the reactor,
- at least one return duct (36) to connect the particle separator (28) with the outer part (12") of the fluidized bed, for returning the solid particles separated in the particle separator to the outer part of the fluidized bed,
- heat transfer surfaces (24, 44, 46) disposed in the return duct and/or in the fluidized bed in the dense suspension area, and
- means for leading solid particles from the inner part (12") of the fluidized bed towards the hot gas inlet duct (16).

11. An apparatus as recited in claim 10, **characterized in that** the return duct (36) is structurally connected with the riser (22) so that the riser wall (24) constitutes part of the return duct wall.

12. An apparatus as recited in claim 10, **characterized in that** the upper section of the chamber (12) encompassing the fluidized bed (14) has the shape of an open vat.

13. An apparatus as recited in claim 10, **characterized in that** the bubbling fluidized bed (14) is arranged in the annular chamber encasing the gas inlet duct (16).

14. An apparatus as recited in claim 13, **characterized in that** the riser (22) is cylindrical and that the return duct (36) forms a narrow

annular space around the riser.

15. An apparatus as recited in claim 10, **characterized in that** the gas inlet duct (16) is a narrow rectangular slot and that the bubbling fluidized bed is contained in the elongated vat (12) disposed adjacent to the narrow slot.

16. An apparatus as recited in claim 10, **characterized in that** the bubbling fluidized bed is contained in the elongated vats disposed on both sides of the narrow slot.

17. An apparatus as recited in claim 10, **characterized in that** the inner part (12") of the bubbling fluidized bed is provided with means (18) for conveying solid particles as an overflow into the hot inlet gas.

18. An apparatus as recited in claim 10, **characterized in that** inner part (12") of the bubbling fluidized bed is provided with means for conveying solid particles by a transporting gas via inlet openings (60) into the hot inlet gas.

19. An apparatus as recited in claim 10, **characterized in that** the outer part (12') of the fluidized bed is provided with heat transfer surfaces (46) for cooling solid particles.

20. An apparatus as recited in claim 10, **characterized in that** the particle separator (28) is connected with the riser (22) by common wall constructions.

21. An apparatus as recited in claim 10, **characterized in that** the hot gas inlet duct (16) is extending into the chamber 12 to the level equal to or above the level of nozzles (52) for introducing fluidization gas into the fluidized bed (14).

22. An apparatus as recited in claim 21, **characterized in that** the hot gas inlet duct (16) is extending into the chamber 12 to the level equal to the level of nozzles (52) for introducing fluidization gas into the fluidized bed (14).

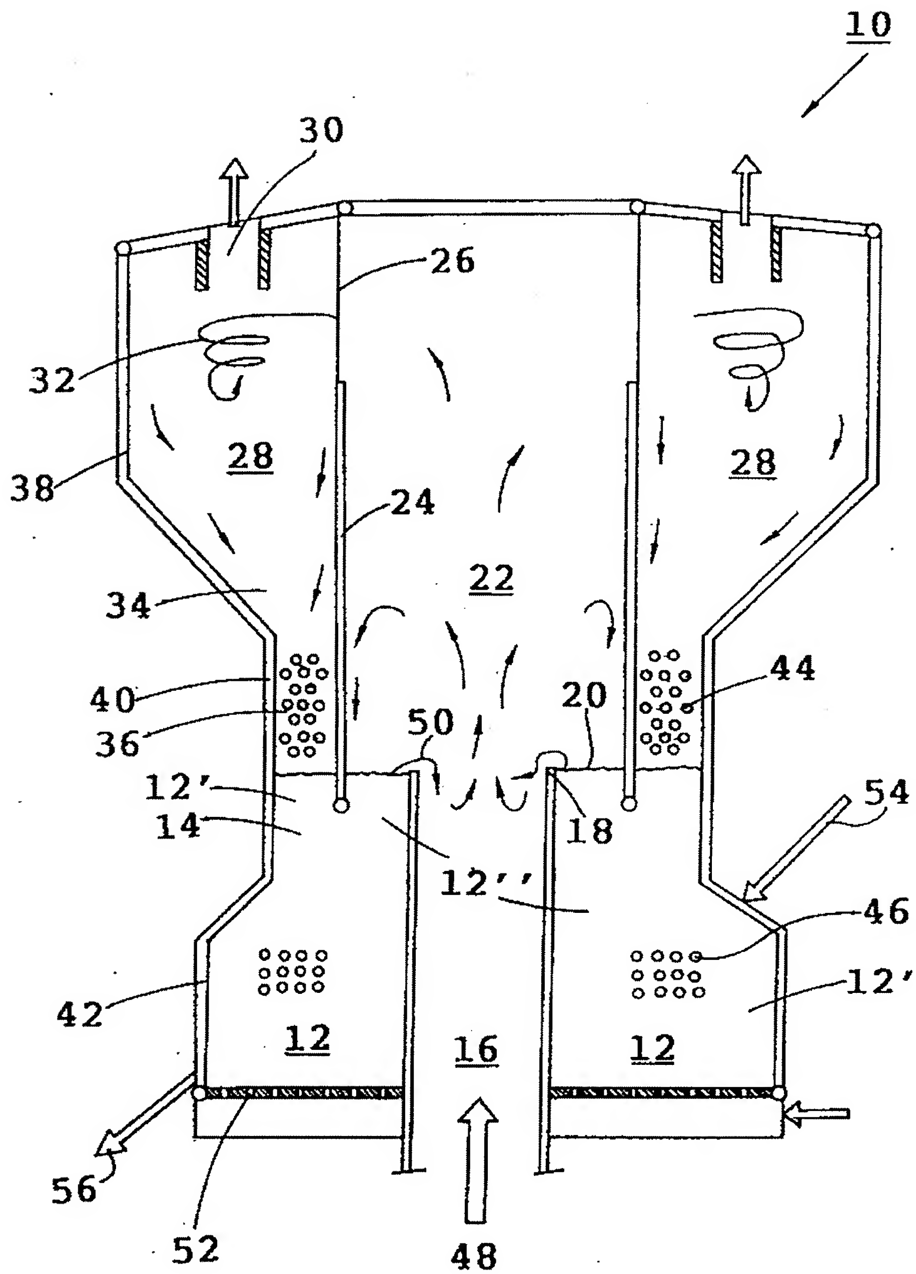
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FIG. 1

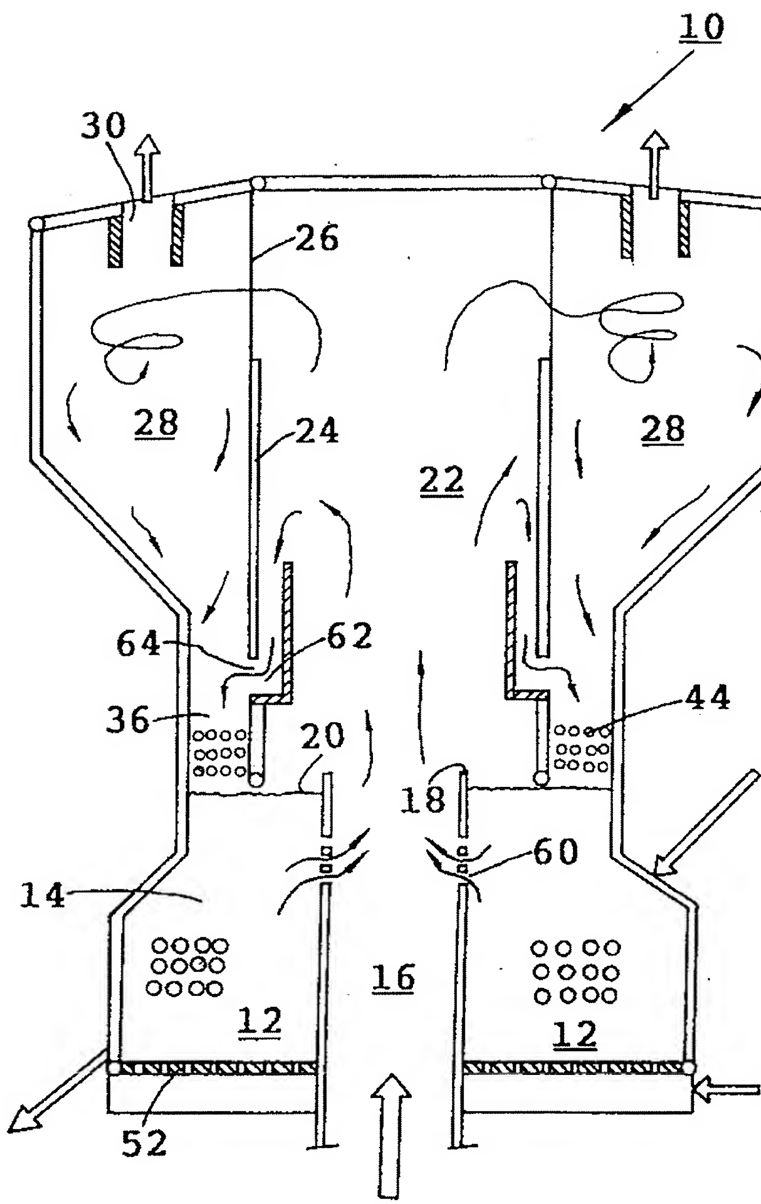

FIG. 2

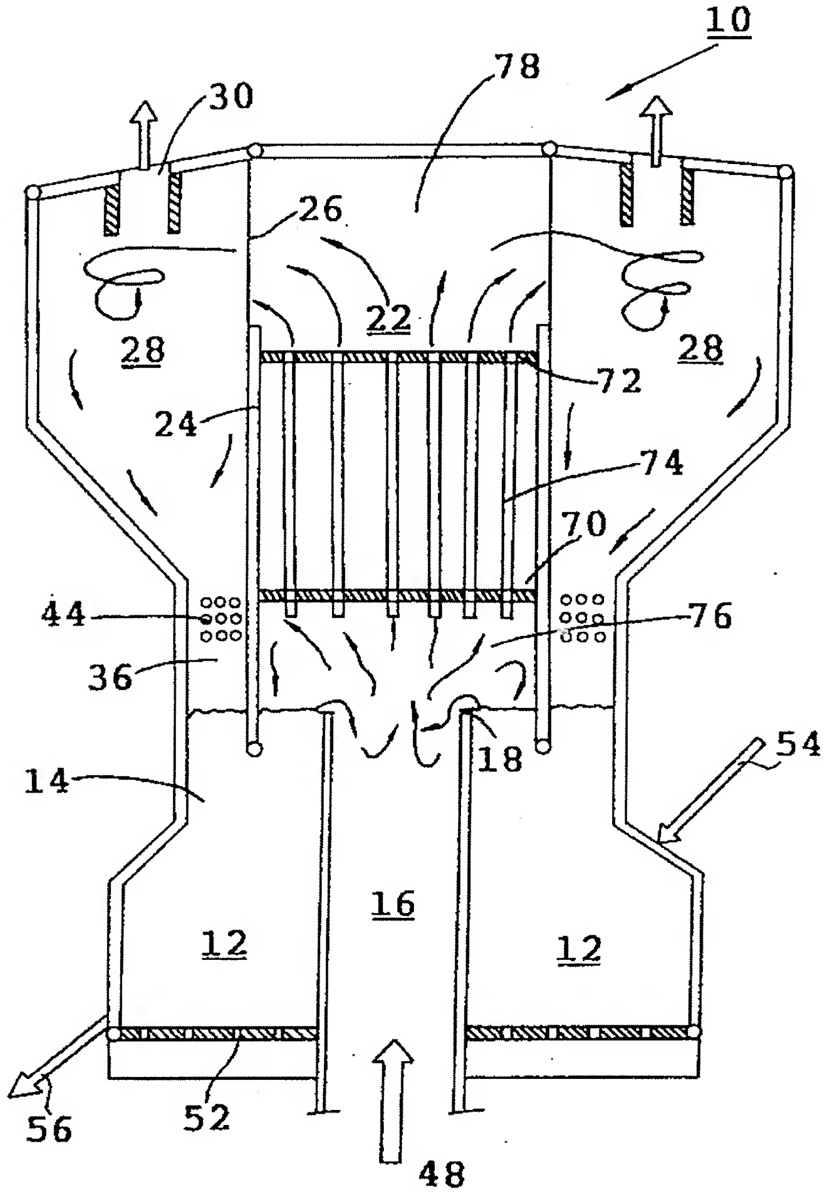

FIG. 3

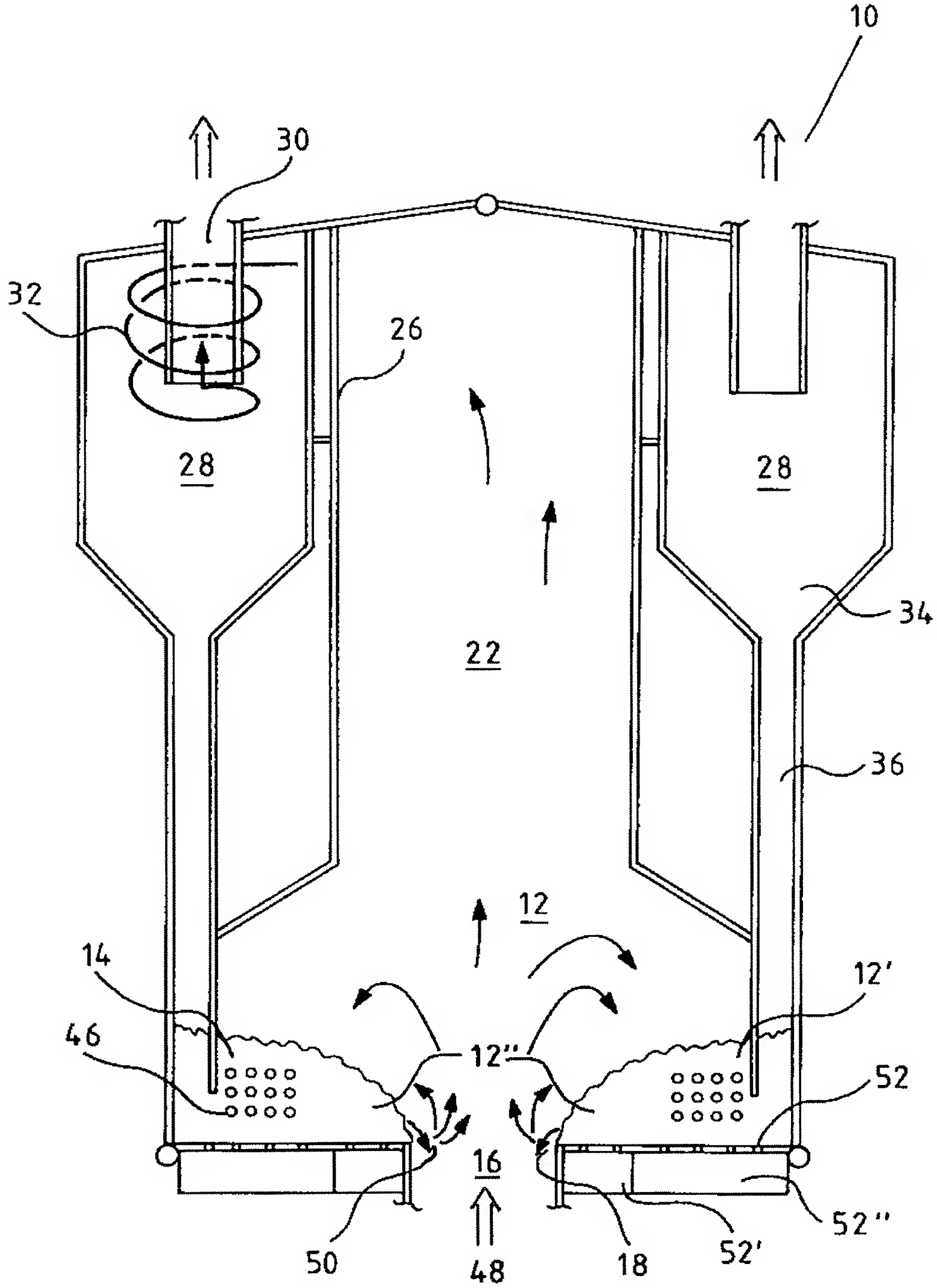

FIG. 4

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 94 10 9722

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
A	EP-A-0 094 795 (EXXON) ---		B01J8/38 F28D13/00 F22B31/00 F28C3/16
A	EP-A-0 282 777 (L & C STEINMÜLLER) ---		
A	GB-A-796 914 (ESSO) ---		
A,D	FI-A-913 416 (METALLGESELLSCHAFT) -----		
			TECHNICAL FIELDS SEARCHED (Int.Cl.5)
			B01J F28D F22B F28C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	23 September 1994	Meertens, J

CATEGORY OF CITED DOCUMENTS

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